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Probabilistic seismic hazard assessment for Romania and sensitivity analysis: A case of joint consideration of intermediate-depth (Vrancea) and shallow (crustal) seismicity

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ABSTRACT

The earthquake risk on Romania is one of the highest in Europe, and seismic hazard for almost half of the territory of Romania is determined by the Vrancea seismic region, which is situated beneath the southern Carpathian Arc. The region is characterized by a high rate of occurrence of large earthquakes in a narrow focal volume at depth from 70 to 160 km. Besides the Vrancea area, several zones of shallow seismicity located within and outside the Romanian territory are considered as seismically dangerous. We present the results of probabilistic seismic hazard analysis, which implemented the "logic tree" approach, and which considered both the intermediate-depth and the shallow seismicity. Various available models of seismicity and ground-motion attenuation were used as the alternative variants. Seismic hazard in terms of macroseismic intensities, peak ground acceleration, and response spectra was evaluated for various return periods. Sensitivity study was performed to analyze the impact of variation of input parameters on the hazard results. The uncertainty on hazard estimates may be reduced by better understanding of parameters of the Vrancea source zone and the zones of crustal seismicity. Reduction of uncertainty associated with the ground-motion models is also very important issue for Romania.

1. Introduction

The earthquake risk on Romania is one of the highest in Europe and seismic hazard for almost half of the territory of Romania is determined by the Vrancea seismic region, which is situated beneath the southern Carpathian Arc (Fig. 1). The region is characterized by a high rate of occurrence of large earthquakes in a narrow focal volume at depth from 70 to 160 km (e.g., [1]). Besides the Vrancea area, several zones of shallow seismicity located within and outside the Romanian territory are considered as seismically dangerous.

The information related to expected seismic effect and expressed in terms of earthquake ground-motion parameters, such as seismic intensity, peak amplitudes of ground motion, pseudo-spectral acceleration (PSA) and ground-motion time histories, is necessary for design of buildings and structures in earthquake prone regions, seismic risk estimation and management, and insurance business. The specification of engineering (or design) ground-motion parameters is the goal of seismic hazard analysis (SHA). It involves the quantitative estimation of ground-shaking hazard at a particular site taking into account characteristics of potentially dangerous earthquakes around the site.

The relation between deterministic and probabilistic approaches for SHA is a subject of much controversy [2–5] (see also discussion in EOS, 2003, 2004, 2005). The decision what approach should be applied depends on (a) the final goal—how and where do we expect to use the result and (b) the parameters of seismicity or likelihood of the worst-case event. Seismic hazard mapping, development of design codes, retrofit design, financial planning of earthquake losses requires mostly probabilistic hazard assessment.

Several studies have been carried out to evaluate the seismic hazard in Romania using the probabilistic approach. Among the most recent ones, which consider the Vrancea seismicity, we should mention the following. Lungu et al. [6,7] calculated the hazard in terms of effective peak acceleration and PSA based on recurrence of large earthquakes. Musson [8] estimated peak ground acceleration for various return periods (probability of exceedence) using stochastic Monte Carlo modeling of the earthquake catalog. The distribution of peak ground acceleration (PGA)

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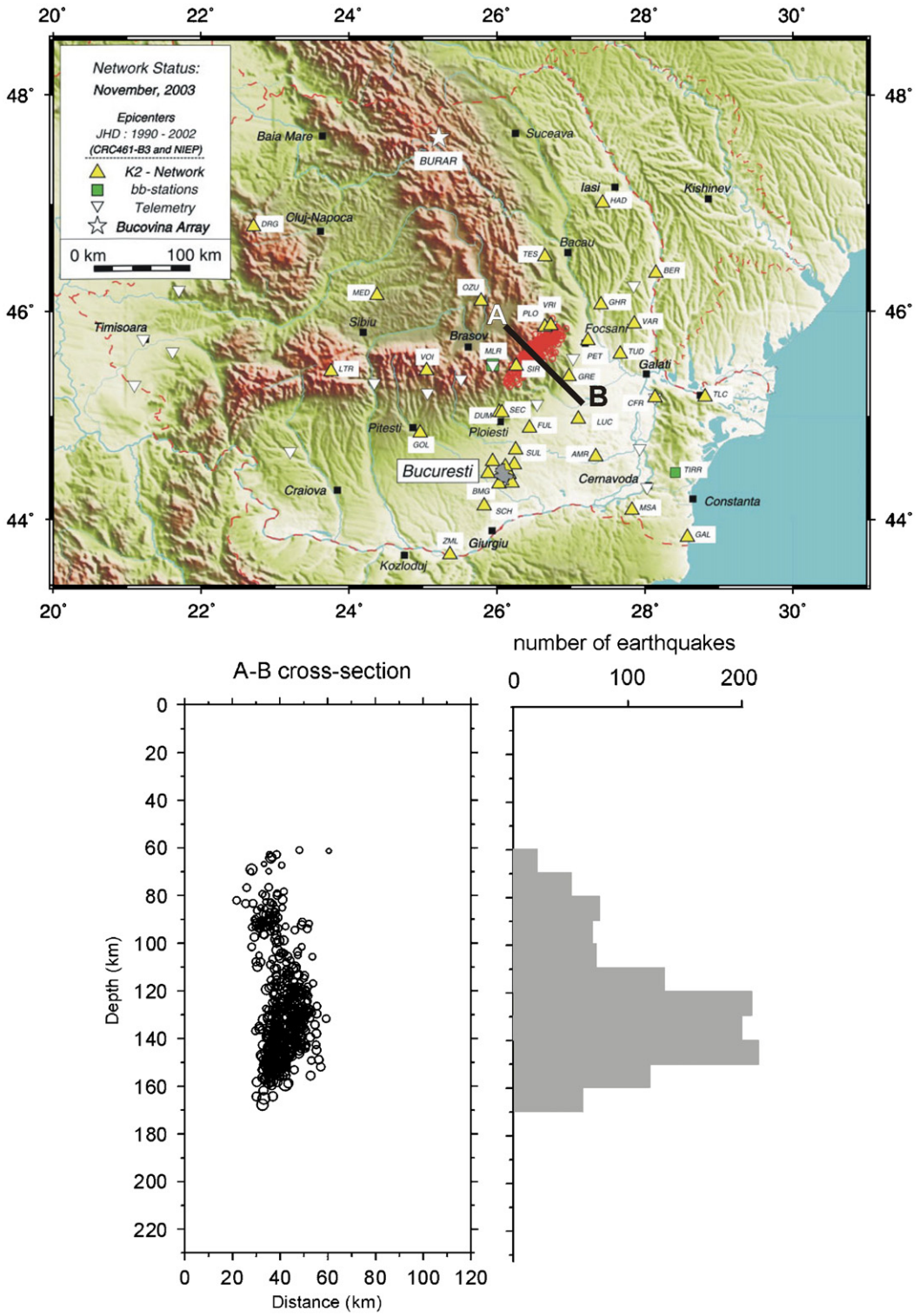

Fig. 1. Epicentral map of the Vrancea earthquakes (1990–2002), depth distribution of hypocenters, and location of permanent digital K2-network stations in Romania.

values for return period of 475 years was calculated by Mantyniemi et al. [9] for three characteristic depths of large earthquakes in the Vrancea area. Ardeleanu et al. [10] performed probabilistic seismic hazard assessment in terms of macroseismic intensities. The results of site-dependent PSHA in terms of macroseismic intensity, PGA, and PSA have been presented by Sokolov et al. [11] for particular locations and by Ismail-Zade et al. [12] for the northern, eastern, and southeastern parts of Romania. Mohindra et al. [13] described probabilistic SHA performed for the whole territory of Romania using so-called "stochastic events" technique and considering both intermediate-depth and crustal seismicity. The crustal and intermediate-depth seismicity were jointly considered also by Musson [8] and Ardeleanu et al. [10]. Moldovan et al. [14,15] estimated seismic hazard from crustal events for central Romania in terms of macroseismic intensity.